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1

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TITLE: A BETA-GAMMA DISCRIMINATOR CIRCUIT

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A BETA-GAMMA DISCRIMINATOR CIRCUIT

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Abstract

The major difficulty encountered in the determination of beta-ray dose in field conditions is generally the presence of a relatively high gamma-ray component. Conventional dosimetry instruments use a shield on the detector to estimate the gamma-ray component in comparison with the beta-ray component. More accurate dosimetry information can be obtained from the measured beta spectrum itself. At Los Alamos, a detector and discriminator circuit suitable for use in a portable spectrometer have been developed. This instrument will discriminate between gammas and betas in a mixed field. The portable package includes a 256-channel MCA [1] which can be programmed to give a variety of outputs, including a spectral display, and may be programmed to read dose directly.

Introduction

An instrument has been developed at Los Alamos which is intended to provide a portable beta spectrometer and dosimeter. The major problem of discriminating between gamma and beta events has been overcome. A combination of special detector and electronics has been developed which is capable of discriminating betas from gammas of moderate energy. Betas interact continuously along a path as they enter a scintillator, while gamma interactions take place at statistically distributed points within the scintillator. This difference provides a means of discriminating volumetrically against gammas while at the same time identifying betas as they enter the detector.

General Description

The heart of the instrument is the special detector that is shown in Figure 1. It consists of a plastic phoswich detector with a thin aluminized mylar window. The front scintillator is 3 mm thick and has a decay time of ~250 ns. The rear scintillator is 2 cm thick and has a decay time of <10 ns. The front scintillator thickness is chosen to provide a good compromise between reliable beta detection and low gamma cross section. A thickness of 3 mm is sufficient to extract 30-40 keV from the entering betas. The rear scintillator should be thick enough to totally stop the most energetic betas of interest, and it must have an efficiency which matches that of the slow scintillator. Discrimination against gammas results from the fact that entering betas deposit some energy in the front scintillator while very few gammas will interact with it because of its small volume. Compton electrons produced in the fast scintillator, which then enter the thin slow scintillator, are generally of somewhat lower energy than the energy deposited by the entering betas and can be partially discriminated against.

The electronics required to accomplish this discrimination is shown in block diagram form in Figure 2. The average waveshapes obtained from the PMT are shown schematically in Figure 3. Output from the PMT is extracted through two paths. An integrating preamplifier is driven by the 11th dynode and a fast linear amplifier is driven by the anode. The integrated signal sums the total energy deposited in both scintillators, and these pulses provide the spectroscopic information. The fast amplifier signal is fed to a discriminator to detect the pulse start timing and to the input of a fast gated integrator. Ordinarily, the threshold of this first discriminator is set to reject thermionic noise from the PMT. The pulse start signal from the discriminator is delayed ~100 ns and then triggers a 300 ns wide gate signal to the gated integrator. The output of this integrator feeds a second discriminator which serves to detect the presence of a signal from the slow scintillator. If the PMT signal has the tail shown in Figure 3c, there will be significant output from the fast gated integrator and therefore from the second discriminator. The presence of this output serves to indicate that the event was due to an event in the slow scintillator, most likely an incident beta particle. The slow integrated signal obtained from the 11th dynode is collected by a multichannel analyzer (MCA) with a gated ADC. This gate is obtained from the beta detection circuit just described and, when run in the coincidence mode, allows the MCA to record pulses only from beta events.

Observations

The initial development was done on a system made up of NIM modules and a commercially available MCA. Typical results are shown in Figure 4. The ungated spectrum shown in Figure 4a was taken in a mixed field with about 5 gammas to 1 beta. Figure 4b shows the spectrum obtained in this mixed field with the beta discrimination applied. A gated spectrum of just the beta source is shown in Figure 4c. As can be seen from the total counts recorded in each case, the discrimination against gammas is about 50:1, in good agreement with the ratio of 67:1 expected for the scintillator thicknesses used.

After it was established that this method of discrimination was feasible, work was started on design of the electronics suitable for a portable instrument. The MCA used was a variation of the units developed at Los Alamos [1,2] for a variety of applications. The front end electronics have been designed and partially developed. We anticipate this instrument will work well in gamma fields of energy up to approximately 1.5 MeV.

Fast plastic scintillators typically exhibit a slow afterglow of a few percent, with a time constant of about 2 µs. This emission interferes with the discrimination against gammas of energy appreciably higher than 1-2 MeV. Since there is wide application for an instrument capable of discriminating against higher energy gammas, it is of interest to decrease this effect significantly or to eliminate it completely. The several different fast plastics we have examined have significantly different levels of afterglow. This suggests that a material might be produced with much lower delayed emission. A promising material has been found in which the afterglow has been reduced by special doping. Work is progressing on construction of a detector package which will allow this circuit to perform the discrimination against gammas of several MeV energy.

Another approach being pursued is to separate the two scintillator signals optically by coupling them separately to two PMTs, thus removing any energy dependence in the discrimination. This scheme has the advantage of using simpler electronics, as no fast amplifiers or delays are needed. The thin scintillator may have a fast decay time, so that light pipe losses can be partially compensated by using a high efficiency plastic. Preliminary measurements with a detector of this type are very encouraging.

Summary

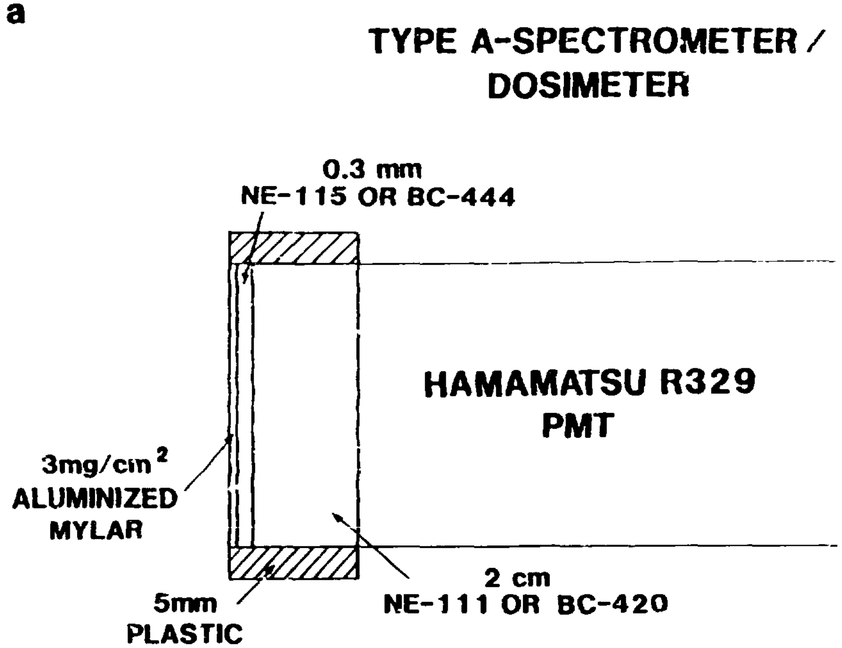
A practical method has been demonstrated to obtain a usable beta spectrum in a mixed beta-gamma field. This is useful in field work where a pure beta field is seldom encountered. The method of discrimination described can be implemented in a field-portable instrument capable of both measuring the spectrum and calculating the skin dose, as well as the dose at any tissue depth in the mixed field. Such an instrument is now in final development.

References

[1] C. J. Umbarger, M. A. Wolf, and F. Trujillo, "Violinist: Sophisticated Pu Field Monitor," IEEE Trans. on Nuclear Science, Vol. NS 31, No. 1, Feb., 1984, Pg. 659.

[2] M. A. Wolf, H. C. Staley, "Simple MCA Supports Variety of Applications," submitted to the 1984 IEEE Nuclear Science Symposium.

a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PLASTIC
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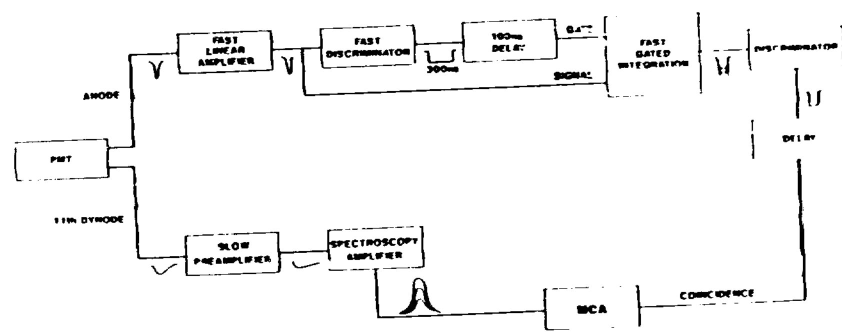
NE-111 OR BC-420

Figure 1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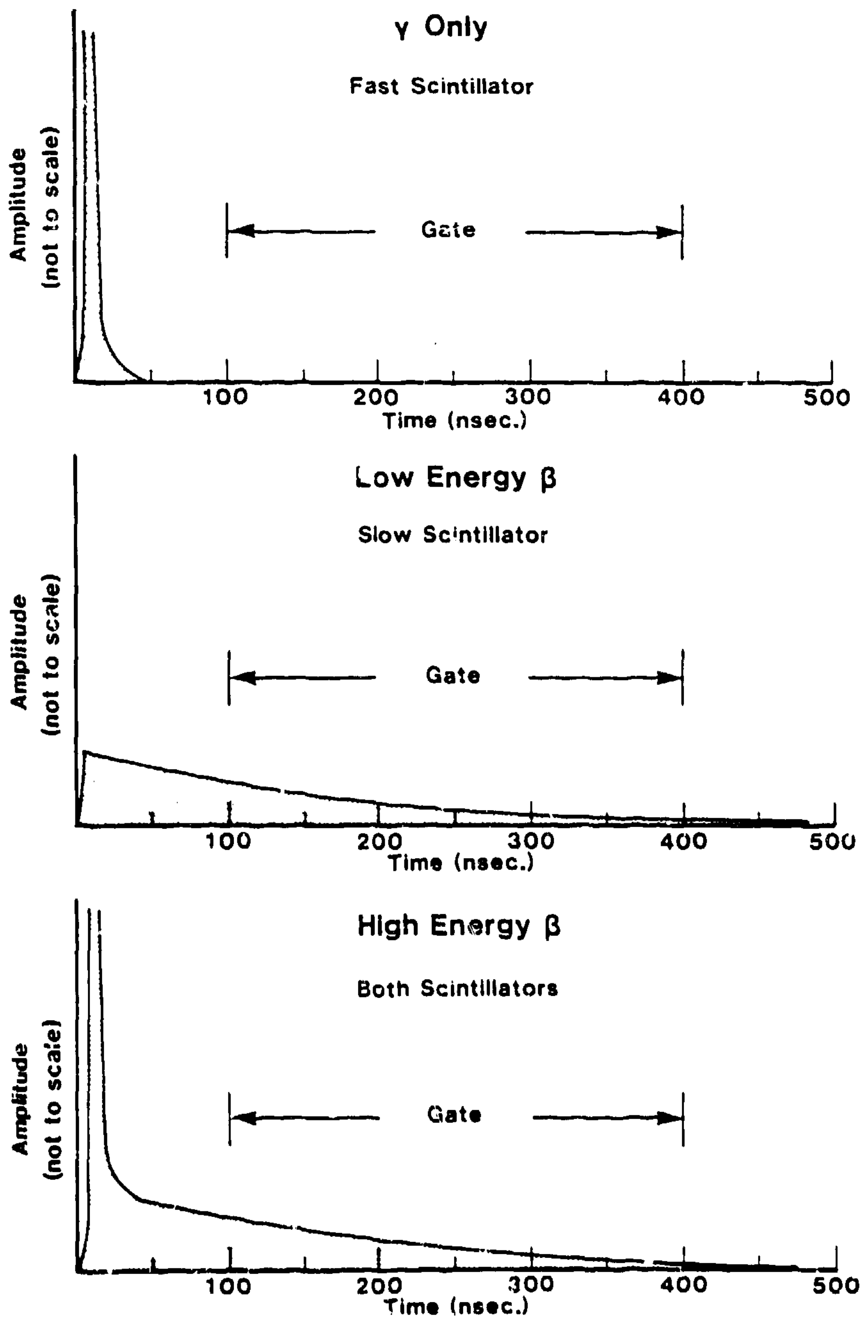
SPECTROSCOPY
AMPLIFIER
COINCIDENCE

Figure 2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Amplitude
(not to scale)
Gate
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200
300
400
500
Time (nsec.)
Low Energy β
Slow Scintillator
Amplitude
(not to scale)
Gate
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300
400
500
Time (nsec.)
High Energy β
Both Scintillators
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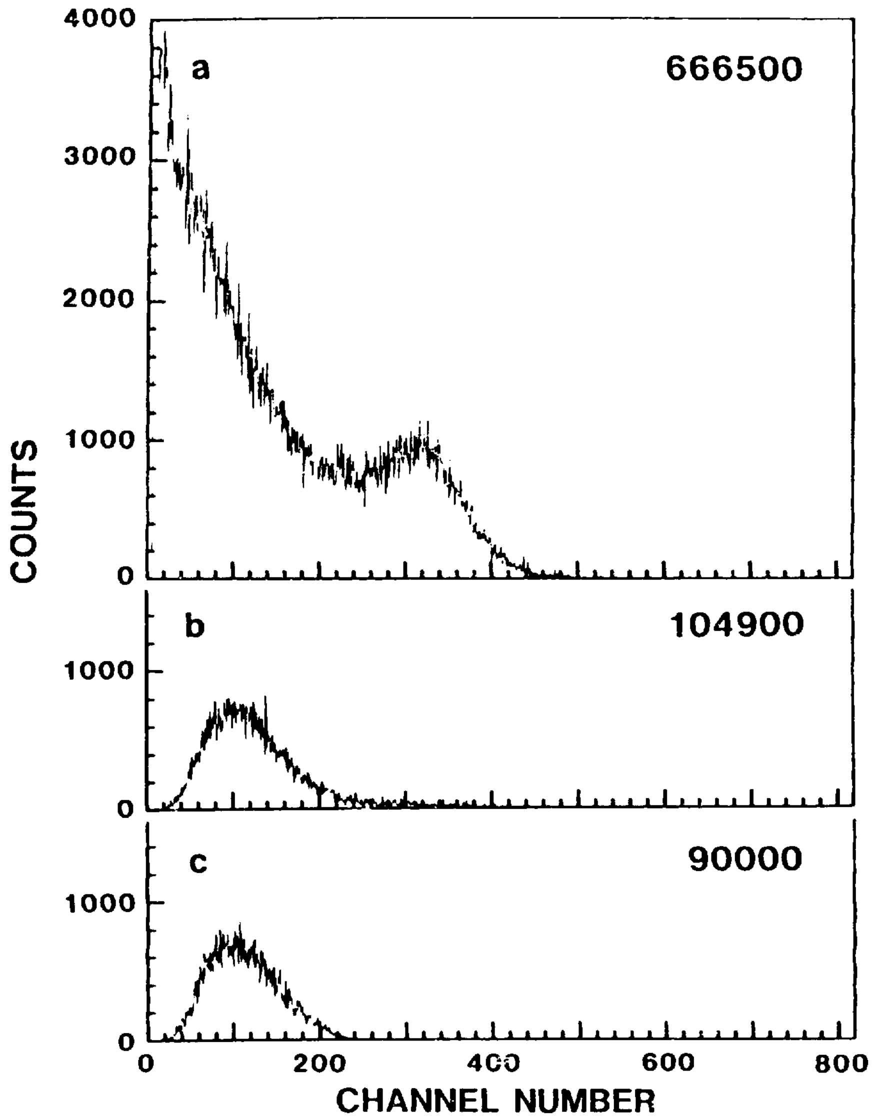
Gate
100
200
300
400
500
Time (nsec.)

Figure 3



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CHANNEL NUMBER

Figure 4